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(54) **Trihydrocarbyl aluminium cocatalysts for olefin polymerization, and use thereof.**

(57) Catalyst compositions for use in olefin polymerization are a mixture of:

(a) $TiCl_3$, $TiCl_4$, $TiBr_3$, $TiBr_4$ or a mixture thereof on a support;

(b) an alkyl metal compound having the formula: $R_nMR'_{3-n}$ or $R_3''M$ wherein R' is C_1 to C_{20} primary alkyl, alkenyl, aralkyl or hydrogen, M is Al, Ga or In, R is a C_3–C_{20} secondary or tertiary alkyl, neopentyl alkyl, cycloalkyl, alkenyl or aralkyl group, n is equal to 0–2; R'' is C_1–C_{20} primary alkyl, secondary alkyl, tertiary alkyl cycloalkyl, alkenyl or an aralkyl group; wherein said composition includes at least one Lewis base, preferably an amine, ester, phosphine, phosphine oxide, phosphate, amide, ketone or ether, the molar ratio of said alkyl metal compound to said transition metal compound being 0.5 : 1 to 200 : 1; and

(c) an alkoxide, carboxylate or aryloxide of a Group IA to Group IIIB metal, the concentration of said metal salt being 0.1 to 20 moles per mole of alkyl metal compound.

Polymerization of an olefin using this catalyst composition is also described.

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It is well known in the art to use an alkyl metal compound of Groups I-III in combination with a transition metal compound of Groups IVA-VIII as a catalyst system for olefinic polymerization. While nearly all of the alkyl metal compounds are effective for the polymerization of ethylene, only a few are effective for the preparation of isotactic polymers of propylene and higher alpha olefins and only Et_2AlCl, $AlEt_3$ and $i\text{-}Bu_2AlH$ have any important commercial utility.

A major cost involved in the polymerization of the alpha olefins is the cost of the catalyst components. Therefore, the cost of the manufacture of the polymer can be effectively reduced by the use of catalyst systems having a higher polymerization activity. A further concern is the ability to produce polymers having a minimum amount of catalyst residues thereby eliminating a costly deashing operation. A still further concern is the ability to produce polymers having a high degree of isotactic stereoregularity thereby enabling the manufacturer to eliminate or reduce the costly operation involving the removal and separation of atactic polymer from the isotactic polymer. The improved catalyst system of the present invention provides a means for the manufacturer to obtain these desirable realizations.

The improved catalyst systems of the present invention which are employed in alpha olefin polymerizations include a Group IVA-VIII transition metal compound, one or more Lewis bases, and at least one metal alkyl compound at least one of which is a metal trialkyl compound of Al, Ga or In, wherein at least one of the alkyl groups is a C_3 to C_{20} secondary or tertiary alkyl, cycloalkyl, alkenyl or aralkyl group.

The transition metal catalyst compound is a Group IVA-VIII transition metal halide, wherein the halide group is chloride or bromide and the transition metal halide may be in the form of solid crystalline compounds, solid solutions or compositions with other metal salts and is supported on the surface of a wide range of solid supports. For highest stereospecificity it is desirable to have the transition metal halide, or its support composition, in the layer lattice structure with very small crystallites, high surface area, or sufficient defects or foreign components to facilitate high dispersion during polymerization. The transition metal halide component may also include various additives such as Lewis bases, pi bases, polymers or organic or inorganic modifiers. Vanadium and titanium halides such as VCl_3, VBr_3, $TiCl_3$, $TiCl_4$, $TiBr_3$ or $TiBr_4$ are preferred, most preferably $TiCl_3$ or $TiCl_4$, and mixtures thereof. The most preferred $TiCl_3$ compounds are those which contain $TiCl_4$ edge sites on a layer lattice support such as alpha, delta, or gamma $TiCl_3$ or various structures and modifications of $TiCl_3$, $MgCl_2$ or other inorganic compounds having similar layer lattice structures. The most preferred $TiCl_4$ compounds are those supported on chloride layer lattice compounds such as $MgCl_2$. Other anions may be also present in the support instead of chloride anions, such as other halides, pseudo-halides, alkoxides, hydroxides, oxides or carboxylates, etc., providing that sufficient chloride is available for isospecific site formation. Mixed salts or double salts such as K_2TiCl_6 or $MgTiCl_6$ can be employed alone or in combination with electron donor compounds. Other supports besides $MgCl_2$ which are useful are hydroxychlorides, oxides or other inorganic or organic supports. The most preferred transition metal compound is $TiCl_4$ containing $MgCl_2$ especially in the presence of Lewis bases (electron donor compounds).

The Lewis bases can be employed in combination with the trialkyl metal compound or with the Group IVA-VIII transition metal compound or with both components as long as they do not cause excessive cleavage of metal-carbon bonds or loss of active sites. A wide variety of Lewis bases may be used including such types as tertiary amines, esters, phosphines, phosphine oxides, phosphates (alkyl, aryl), phosphites, hexaalkyl phosphoric triamides, dimethyl sulfoxide, amides, e.g. dimethyl formamide, secondary amines, ethers, epoxides, ketones, saturated and unsaturated heterocycles, or cyclic ethers and mixtures thereof. Typical but non-limiting examples are diethyl ether, dibutyl ether, tetrahydrofuran, ethyl acetate, methyl p-toluate, ethyl p-anisate, ethyl benzoate, phenyl acetate, amyl acetate, methyl octanoate, acetophenone, benzophenone, triethyl amine, tributylamine, dimethyl decylamine, pyridine, N-methylpiperidine, 2,2,6,6-tetramethylpiperidine and the like. The most preferred are esters of carboxylic acids such as ethylbenzoate.

The salts of Group IA-IIIB metals employed with the present catalysts are preferably partially or wholly solubilized by reaction with the alkyl metal components. Particularly useful are the carboxylates, alkoxides and aryloxides of magnesium and aluminum. Non-limiting examples include $Mg(OOCR'')_2$, $R''OMgOOCR''$, $ClMgOR''$, $Mg(OR'')_2$, $R''_2AlOOCC_6H_5$, $R''Al(OOCR'')_2$, R''_2AlOR'', and the like, where R'' is a hydrocarbyl group. Most preferred are the carboxylate salts of magnesium and aluminum prepared *in situ* by reacting the organometal compounds with carboxylic acids in hydrocarbon solvents. These salts of Group IA-IIIB metals are more preferably used with the trialkyl metal compounds having the formula R''_3M wherein M = Al, Ga or In, and R'' is a C_1-C_{20} primary, secondary or tertiary alkyl, cycloalkyl, alkenyl, aralkyl group or a mixture thereof, more preferably at least one of the R'' groups being of C_3-C_{20} neopentyl, secondary or tertiary alkyl, cycloalkyl, alkenyl or aralkyl group. The salt of the Group IA-IIIB metal is used at a concentration level of 0.1 to 20 moles of the salt of Group IA-IIIB metal per mole of the trialkylaluminum compound R''_3Al, more preferably 0.2 to 5 moles, and most preferably 0.5 to 1 mole when the oxygen-containing group is alkoxide or aryloxide. When the group is carboxylate, the ratio is 0.1 to 1, preferably 0.1 to 0.5 carboxylate groups per mole of the trialkyl metal compound. The use of these Group IA-IIIB metal salts is preferably with the supported titanium catalyst systems as embodied in the present invention.

The improved cocatalysts of the present invention have the general formula $R_nMR'_{3-n}$ wherein M = Al, Ga or In, R is a C_3-C_{20} secondary or tertiary alkyl, neopentylalkyl, cycloalkyl, alkenyl or aralkyl group, R' is a C_1-C_{20} primary alkyl, alkenyl or aralkyl or hydride; and n = 0-2, preferably 1-2, and most preferably n = 2. Preferably, R' is C_2-C_{10} primary alkyl or aralkyl or hydrogen most preferably R' is C_2-C_4 primary alkyl or hydrogen, preferably not more than one hydrogen being present. The R group is preferably a C_4-C_{16} secondary or tertiary alkyl group or cycloalkyl group and is most preferably one which is not readily susceptible to elimination or displacement by monomer during polymerization. In addition to the simple secondary alkyl groups other groups are also effective, in which the aluminum is attached to a secondary or tertiary carbon atoms, i.e., cyclohexyl, cyclooctyl, tert-butyl, tert-amyl, s-norbornyl, and the like. The most preferred compositions have the formula $R_nAlR'_{3-n}$ in which the secondary and tertiary alkyl groups contain 4-10 carbons and n = 2. Mixtures of the cocatalysts of this invention with conventional alkyl metal cocatalysts also yield improved results.

Suitable non-limiting examples include i-Pr_2AlEt, s-$BuAlEt_2$, s-Bu_2AlEt, t-$BuAlEt_2$, t-Bu_2AlEt, s-Bu_3Al, 1,1-dimethylheptyl $AlEt_2$, s-Bu_2Aln-$C_{16}H_{33}$, t-$Bu_2AlCH_2C_6H_5$, s-Bu(t-Bu)Aln-Bu, cyclohexyl$_2$AlEt, s-pentyl Ali-Bu_2, t-Bu_2AlMe, t-Bu_2Aln-C_8H_{17}, (2-ethylcyclopentyl)$_2$AlEt, 2-(3-ethylnorbornyl)$AlEt_2$, 2-norbornyl Ali-Bu_2, (2-norbornyl)$_2$ Ali-Bu, acenaphthyl Ali-Bu_2, cyclooctyl (i-Bu) AlH, 3-ethyl-5-ethylidinenorbornyl $AlEt_2$, 9-i-bu-9-alumino-3,3,1-bicyclononane, s-Bu_2AlH, t-Bu_2AlH, t-Bu_2InEt, s-Bu_2GaEt, neopentyl $AlEt_2$, neopentyl$_2$ AlEt and the like.

Preferred compounds include those in the above list which have the formula $R_{1-2}AlR'_{2-1}$. The most preferred compounds in the above list have the formula R_2AlR'.

One method of preparing these secondary alkyl aluminum compounds is to react internal olefins with $AliBu_3$ or i-Bu_2AlH to add Al-H across the double bond to form alkyl aluminum compounds. When the double bond is in a strained ring compound, AlR_3 may be used to add Al-R across the double bond and obtain preferred compounds which are very resistant to displacement or elimination. Strained ring olefins include cyclopentene, norbornene, norbornadiene, ethylidine norbornene, dicyclopentadiene, and the like. This method is preferred because of raw material availability and simplicity of reaction, although this invention is not limited by the method of synthesis.

Other methods include the direct synthesis from the reactive metals and the secondary or tertiary halides, the various organometallic syntheses involving ligand exchange between Al, Ga or In compounds and secondary or tertiary alkyl metal compounds of more electropositive metals such as Groups IA and IIA, and the reaction of the metals with the alkyl mercury compounds. Particularly useful is the general reaction of secondary or tertiary alkyl lithium compounds with $R'MX_2$ or R'_2MX because it takes place readily in dilute hydrocarbon solutions.

Although di-secondary alkyl aluminum compounds are preferred to mono-secondary alkyl compounds, the monoalkyl types become more effective the greater the steric bulk of the group as long as it does not interfere with active site formation or lead to decomposition under reaction conditions.

For the alkyl metal cocatalysts of this invention, the most preferred transition metal compounds contain $TiCl_4$ supported on $MgCl_2$ and one or more Lewis bases. The concentration of the transition metal in the polymerization zone is 0.001 to about 5mM, preferably less than 0.1mM.

The molar ratio of the trialkyl metal compound to the transition metal compound is 0.5:1 to 200:1 more preferably 10:1 to 100:1. The molar ratio of Lewis base to organometal compound can vary widely but is preferably 0.1:1 to 1:1.

The catalyst system of the invention enables the process for making alpha olefin polymers having a high degree of isotactic stereoregularity to be carried out at a temperature of 25° to 150°C., more preferably 40° to 80°C., at pressures of 1 atm. to 50 atm. The reaction time for polymerization is 0.1 to 10 hours, more preferably 0.5 to 3 hours. Due to the high catalyst activity, shorter times and temperatures below 80°C. can be readily employed.

The reaction solvent for the system can be any inert paraffinic, naphthenic or aromatic hydrocarbon such as benzene, toluene, xylene, propane, butane, pentane, hexane, heptane, cyclohexane, and mixtures thereof. Preferably, excess liquid monomer is used as solvent. Gas phase polymerizations may also be carried out with or without minor amounts of solvent.

Typical, but non limiting examples of C_2-C_{20} alpha olefinic monomers employed in the present invention for the manufacture of homo-, co- and terpolymers are ethylene, propylene, butene-1, pentene-1, hexene-1, octadecene-1, 3-methylbutene-1, styrene, ethylidene norbornene, 1,5-hexadiene and the like and mixtures thereof. Isotactic polymerization of propylene and higher olefins is especially preferred, including block copolymerizations with ethylene.

The trialkyl metal compound and the supported transition metal compound can be added separately to the reactor or premixed before addition to the reactor, but are preferably added separately. Replacing the secondary or tertiary alkyl groups by bulky or hindered alkoxy, phenoxy or dialkylamide groups does not provide the improved catalyst activity achieved by the cocatalyst in this invention.

An alternative embodiment of the present invention with respect to the cocatalysts ($R_nMR'_{3-n}$) is to use directly the reaction product of $R_2Mg + R'MX_2 \longrightarrow R_2MR' + MgX_2$ as exemplified in Belgian patent 863827; or $RMgX' + R'_2MX \longrightarrow$

$RMR'_2 + MgXX'$ as exemplified in Belgian patent 863823,

In the case of the formation of R_2MR', the metal di- or trihalide compounds which are used are selected from the group consisting of a metal halide compound selected from the group consisting of $R'MX_2$, MX_3 and mixtures thereof, wherein M is selected from the group consisting of Al, Ga and In, R' is selected from the group consisting of C_1 to C_{20} primary alkyl, alkenyl or aralkyl groups or hydride; X is selected from the group consisting of chloride, bromide or a monovalent anion which cannot initiate polymerization of olefinic monomers, wherein the anion is selected from the group consisting of alkoxide, phenoxide, thioalkoxide, carboxylate, etc. and mixtures thereof. Typical but non-limiting examples are ethyl aluminum dichloride, aluminum trichloride, ethyl aluminum dibromide, ethyl chloroaluminum bromide, octyl aluminum dichloride, ethyl indium dichloride, butyl aluminum dichloride, benzyl aluminum dichloride, ethyl chloroaluminum butoxide, and mixtures thereof. Mixtures of metal halide compounds can be readily employed.

The C_2-C_4 alkyl aluminum dihalides are most preferred for high stereospecificity and the monoalkylaluminum dichlorides are most preferred.

The diorganomagnesium compound has the general formula R_2Mg wherein R can be the same or different and is a C_3 to C_{20} secondary or tertiary alkyl, cycloalkyl, aralkyl or alkenyl groups. Typical, but non limiting examples are $(s\text{-}Bu)_2Mg$, $(t\text{-}Bu)_2Mg$ or $(iPr)_2Mg$. Mixtures of diorganomagnesium compounds can be readily employed providing at least one secondary or tertiary group is present. The most preferred organic groups are secondary and tertiary alkyl groups, e.g. t-Bu or s-Bu.

The molar ratio of the alkyl metal halide compound ($R'MX_2$) to the diorganomagnesium compound is critical and is 0.5:1 to 2:1, more preferably 0.7:1, and most preferably 1:1. For the MX_3 compound the ratio is 1:1 to 1:3, most preferably 2:3. The number of moles of Lewis base can vary widely but is preferably equal to or less than the sum of the moles of the metal halide compound and the diorganomagnesium compound. The molar ratio of the metal halide compound or the diorganomagnesium compound to the transition metal compound is less than 200:1 and more preferably less than 100:1.

The metal halide compound and diorganomagnesium compound can be added separately to the reactor containing the transition metal compound but are preferably premixed before addition to the reactor. Employing either the metal halide compound or the diorganomagnesium compound alone with the transition metal compound does not provide the improved catalyst efficiency and stereospecificity as envisioned in this application. In order to attain this, it is necessary to employ both the metal halide compound and diorganomagnesium compound in combination with the transition metal compound in the critical proportions as previously defined. The concentration of the transition metal in the polymerization zone is 0.001 to 5mM, preferably less than 0.1mM.

In the case of the formation of RMR'_2, the metal alkyl compounds which are used are

R'_2MX or R'_3M and mixtures thereof, wherein M is selected from the group consisting of Al, Ga and In, R' is selected from the group consisting of C_1 to C_{20} primary alkyl, alkenyl, aralkyl or hydride groups; X is selected from the group consisting of a monovalent anion which cannot initiate polymerization of olefins, such as F, Cl, Br, OR", SR", and OOCR", wherein R" is selected from the group consisting of C_1 to C_{20} alkyl, branched alkyl, cycloalkyl, aryl, naphthenic, aralkyl and alkenyl groups, X is more preferably Cl or Br and most preferably Cl. Typical but non-limiting examples are diethyl aluminum chloride, aluminum triethyl, diethylaluminum bromide, diethylaluminum iodide, diethylaluminum benzoate, diisobutylaluminum hydride, dioctylaluminum chloride, diethylgallium butoxide, diethylindium neodecanoate, triethylindium, dibenzylaluminum chloride and mixtures thereof. Mixtures of metal alkyl compounds can be readily employed. The C_2-C_4 alkyl aluminum compounds are preferred for high stereospecificity and the dialkyl aluminum chlorides are most preferred.

The mono-organomagnesium compound has the general formula RMgX' wherein R is a C_3 to C_{20} secondary or tertiary alkyl, cycloalkyl, aralkyl or alkenyl groups. X' is an anion which cannot initiate polymerization of olefins, such as Cl, Br, OR", SR", and OOCR", wherein R" is a C_1 to C_{20} alkyl, branched alkyl, cycloalkyl, naphthenic, aryl, aralkyl, allyl or alkenyl group. Typical, but non limiting examples are s-BuMgCl, t-BuMgCl, s-$BuMgOOCC_6H_5$, or s-$BuMgOC_{15}H_{31}$, and mixtures thereof. Mixtures of organomagnesium compounds can be readily employed. The most preferred X' groups are OR" and OOCR" and the most preferred R groups are secondary or tertiary alkyls.

The molar ratio of the organomagnesium RMgX' compound to the metal alkyl compound (R'_2MX or R'_3M) is 2:1 to about 1:2, most preferably about 1:1. The number of moles of Lewis base can vary widely but is preferably equal to or less than the sum of the moles of the metal alkyl compound and the organomagnesium compound. The molar ratio of the metal alkyl compound or the organomagnesium compound to the transition metal compound is less than 200:1 and more preferably less than 100:1.

The metal alkyl compound (R'_2MX or R'_3M) and organomagnesium compound RMgX' can be added separately to the reactor containing the transition metal compound but are preferably premixed before addition to the reactor. Employing either the metal alkyl compound or the organomagnesium compound alone with the transition metal compound does not provide the improved catalyst efficiency and stereospecificity as envisioned in this application. In order to attain this, it is necessary to employ both the metal alkyl compound and organomagnesium compound in combination with the transition metal compound in the proportions previously defined. The concentration of the transition metal in the polymerization zone is 0.001 to 5mM, preferably less than 0.1mM.

The advantages of the unique and novel catalyst system and the novel process for the alpha olefin polymerizations of the present invention can be more readily appreciated by reference to the following examples and tables.

EXAMPLE 1

An aluminum alkyl compound containing both sec-butyl and ethyl groups was prepared by mixing equimolar amounts of $(\text{sec-butyl})_2Mg\cdot0.16\ Et_2O$ and ethyl aluminum dichloride in heptane, heating to 65°C., 15 min., separating the magnesium chloride solids and vacuum stripping the clear solution. NMR analysis indicated the composition $sBu_2AlEt\cdot0.45Et_2O$. Metals analysis showed that only 0.50% Mg was present in this fraction.

The above liquid alkyl aluminum compound (0.2 g) was used as cocatalyst with 0.2 g catalyst prepared by reacting anhydrous $MgCl_2$ (5 moles) with $TiCl_4\cdot C_6H_5COOEt$ (1 mole) in a ball mill 4 days, followed by a neat $TiCl_4$ treat at 80°C., 2 hours, washed with heptane and vacuum dried. The catalyst contained 2.68% Ti. Propylene was polymerized in 500 ml n-heptane at 65°C., 1 hour at 765-770mm. Polymerization rate was 130 g/g catalyst/hour and the polymer insoluble in boiling heptane = 97.6%.

EXAMPLE 2

Three alkyl aluminum compounds containing sec-butyl groups were prepared by reacting the proper stoichiometric amounts of sec-butyl lithium in heptane with either ethyl aluminum dichloride or diethylaluminum chloride, heating to boiling, filtering the insoluble LiCl, and vacuum stripping the clear solutions. Nearly theoretical yields were obtained of s-BuEtAlCl (A), s-Bu_2EtAl (B) and s-BuEt_2Al (C). Compositions were established by ^1H and ^{13}C NMR and by G.C. analysis of the alkyl fragments.

Polymerizations were carried out as in Example 1 using 1 mmole aluminum alkyl compound and 0.2 g of the supported $TiCl_4$ catalyst. The results summarized in Table I are compared to those obtained using the control ethyl aluminum compounds. In all three runs with sec-butyl alkyls, both activity and stereospecificity (heptane insolubles) were higher than those obtained with the conventional ethyl aluminum compounds. The trialkyls were far superior to the dialkyl aluminum chlorides and the di-sec-butyl aluminum ethyl was clearly superior to the mono-sec-butyl aluminum diethyl compound.

TABLE I

Run	Al Alkyl	Rate g/g Cat/hour	% HI
A	Et_2AlCl control	48.9	68.0
B	s-$Bu_{1.07}EtAlCl_{0.93}$	64.6	79.1
C	Et_3Al control	344	83.1

D	s-$BuEt_2Al$	380	90.3
E	s-Bu_2EtAl	357	93.0

EXAMPLE 3

Sec-pentyl aluminum diisobutyl was prepared by reacting 19.57 g i-Bu_2AlH with 75 ml pentene-2 in a glass lined 300 cc bomb at 135-140°C. for 16 hours, then 150°C. for 7 hours. The solution was vacuum stripped at 25°C., yielding 28.1 g of the neat sec-pentyl aluminum compound.

Propylene was polymerized as in Example 2 using 0.212 g (1 mmole) sec-pentyl aluminum diisobutyl as cocatalyst. Polymerization rate was 383 g/g Cat/hr and % HI = 92.7. Comparison with $AlEt_3$ control (Ex. 2,, Run C) shows that the sec-pentyl aluminum compound gave substantial improvement, particularly in stereospecificity.

EXAMPLE 4

The alkyl metal cocatalysts of the invention are particularly advantageous in having a much smaller effect of concentration (or alkyl metal/Ti) on stereospecificity, thereby simplifying plant operation and permitting better control of product quality. The results are summarized in Table II for di-sec-butyl aluminum ethyl in contrast to $AlEt_3$ using the propylene polymerization procedure of Example 2.

TABLE II

Run	Al Alkyl	Conc., mM	Rate	% HI
F	s-Bu_2AlEt	2	357	93.0
G	s-Bu_2AlEt	4	484	83.4
H	$AlEt_3$ Control	2	344	83.1
I	$AlEt_3$ Control	4	290	64.9

The above examples illustrate that trialkyl aluminum compounds containing at least one secondary alkyl group are superior cocatalysts in Ziegler type polymerizations of alpha olefins and that di-secondary alkyl aluminum compounds are preferred.

EXAMPLE 5

Various secondary norbornyl aluminum n-alkyl compounds were prepared by reacting the stoichiometric proportions of a norbornene compound with either $i\text{-}Bu_2AlH$ or $AlEt_3$ at elevated temperatures and removing unreacted materials by vacuum stripping. Structures were shown by ^1H and ^{13}C NMR to be the expected addition products of Al-H or Al-Et across the norbornene double bond. These mono and di-secondary alkyl aluminum compounds were used in propylene polymerization following the procedure of Example 2.

TABLE III

Run	Al Alkyl	Rate	% HI
J	2-Norbornyl $AliBu_2$*	344	90.2
K	$(2\text{-Norbornyl})_2AliBu$*	247	91.8
L	3-Ethyl-2-norbornyl $AlEt_2$*	322	92.5
M	3-Ethyl-5-ethylidine-2-norbornyl $AlEt_2$*	247	93.7

* Other isomers may also be present.

Comparison with the $AlEt_3$ control (Run C, Example 2) shows that all of the secondary norbornyl aluminum alkyls gave markedly higher heptane insolubles while retaining high activity.

EXAMPLE 6

Sec-alkyl aluminum hydrides also give improved results compared to the closely related primary alkyl aluminum hydride ($i\text{-}Bu_2AlH$), following the procedure of Example 2.

TABLE IV

Run	Al Alkyl	Rate	% HI
N	$i\text{-}Bu_2AlH$ control	456	83.1
O	$s\text{-}Bu_{2.6}AlH_{0.4}$	462	85.8
P*	$AlEt_3$ control	241	82.3
Q*	iBu_3Al control	264	89.3
R*	$s\text{-}Bu_{2.6}AlH_{0.4}$	284	90.7
S*	$s\text{-}Bu_{2.3}AlH_{0.7}$	223	90.1

* Another catalyst preparation was used. It was made by ball milling 5 moles $MgCl_2$ with 1 mole ethylbenzoate for one day, adding 1 mole $TiCl_4$ and milling 3 days, then treating with neat $TiCl_4$ at 80°C., 2 hours, washing with heptane and vacuum dried. The catalyst contained 3.44% Ti.

Run O using sec-butyl groups gave higher activity and stereospecificity than Run N using the closely related, but primary, isobutyl groups. Improved results are also seen versus the $AlEt_3$ control using the same supported titanium catalyst (Example 2, Run C).

Runs R and S show substantially higher heptane insolubles using two different sec-butyl aluminum hydrides compared to control Runs P and Q using $AlEt_3$ and iBu_3Al with the same catalyst.

EXAMPLE 7

The procedure of Example 2 was followed except that various Lewis bases were mixed with the aluminum alkyl solution before charging to the reactor.

TABLE V

Run	Al Alkyl	mmoles Base	Rate	% HI
T	$AlEt_3$ control	0.16 Et_2O	358	84.7
U	s-Bu_2AlEt	0.16 Et_2O	289	94.4
V	t-Bu_2AlEt	0.1 Me p-toluate	327	94.0
W	t-Bu_2AlEt	0.3 Et p-anisate	79	97.3
X	t-Bu_2AlEt	0.9 Et_2O	56	98.0
Y	t-$BuAlEt_2$	0.9 Et_2O	101	97.1
Z*	t-Bu_2AlEt	0.2 acetophenone	196	94.2
AA*	t-Bu_2AlEt	0.2 ethylacetate	74	97.6

* Used catalyst preparation described in Example 6, Runs P-S.

The improved stereospecificities obtained with the cocatalysts of this invention are further increased by the addition of Lewis bases (Runs U-AA versus control Runs T and Example 2, Run C). At the higher amounts of base, 97-98% HI was obtained, which is sufficiently high to eliminate the need for rejection of atactic polymer and greatly simplify the process. Activity is decreased somewhat, but it is still 3-5 times that of the $Et_2AlCl/TiCl_3 \cdot 0.33AlCl_3$ commercial catalyst (rate = 20, HI = 93). At somewhat lower base concentrations, activity is 10-20 times higher than the commercial catalyst while still achieving 1-2% higher heptane insolubles.

EXAMPLE 8

Following the procedures of Example 2 and Example 7, improved stereospecificity is also obtained using t-Bu_2InEt cocatalyst.

EXAMPLE 9

The procedure of Example 6, Runs P-S was followed except that 9-i-Bu-9-alumino-3,3,1-bicyclononane was used as cocatalyst. Polymerization rate = 97.5 g/g catalyst/hour; HI = 85.1%.

EXAMPLE 10

The procedure of Example 9 was followed except that t-Bu_2Al (n-octyl) was used as cocatalyst. The rate was 212 g/g catalyst/hour; HI = 93.0%.

EXAMPLE 11

Polymerizations were carried out in a 1 liter baffled resin flask fitted with an efficient reflux condenser and a high speed stirrer. In a standard procedure for propylene polymerizations, 475 ml n-heptane (<1 ppm water) containing 10 mmole Et_2AlCl (1.20 g), or the mixture of cocatalysts, was charged to the reactor under dry N_2, heated to reaction temperature (65°C.) and saturated with pure propylene at 765 mm pressure. The $TiCl_3$ (1.00 g) (6.5 mmole) was charged to a catalyst tube containing a stopcock and a rubber septum cap. Polymerization started when the $TiCl_3$ was rinsed into the reactor with 25 ml n-heptane from a syringe. Propylene feed rate was adjusted to maintain an exit gas rate of 200-500 cc/min at a pressure of 765 mm. After one hour at temperature and pressure, the reactor slurry was poured into one liter isopropyl alcohol, stirred 2-4 hours, filtered, washed with alcohol and vacuum dried.

The $TiCl_3$ was prepared by reduction of $TiCl_4$ with Et_2AlCl followed by treatment with diisopentyl ether and $TiCl_4$ under controlled conditions, yielding a high surface area delta $TiCl_3$ having low aluminum content.

The sec-butyl magnesium in Runs B, D and E was obtained from Orgmet and contained 72% non volatile material in excess of the s-Bu_2Mg determined by titration. IR, NMR and GC analyses showed the presence of butoxide groups and 0.07 mole diethyl ether per s-Bu_2Mg. A second sample of $(s\text{-}Bu)_2Mg$ was used in Runs G and I. It was substantially pure s-Bu_2Mg but contained 0.33 mole diethyl ether per s-Bu_2Mg (Table VI).

TABLE VI

Run	g $TiCl_3$	Mmoles $EtAlCl_2$	Mmoles $(s\text{-}Bu)_2Mg$	Mmoles Et_2AlCl	Rate g/g/hr	% HI
A(Control)	1 (a)	0	0	10	33	95.2
B	1 (a)	5	5	0	152	52.6
C(Control)	1 (b)	0	0	10	85	96.3
D	0.2 (b)	0.4	0.2	1.6	123	88.0
E	0.2 (b)	2	2	0	210	49.2
F(Control)	1 (c)	0	0	5	8	79.5
G	1 (c)	2.5	2.5	0	36	57.6
H(Control)	1 (d)	0	0	10	20	91.7
I	0.2 (d)	1	1	0	200	57.4

(a) and (b) were different preparations of low aluminum $TiCl_3$ catalysts.
(c) Stauffer HA grade $TiCl_3$ (hydrogen-reduced, dry ball milled).
(d) Stauffer AA grade $TiCl_3 \cdot 0.33\ AlCl_3$ (aluminum-reduced, dry ball milled).

Comparison of Runs B, D, E, G and I with their respective control runs A, C, F and H shows that each type of $TiCl_3$ catalyst the novel cocatalyst combination gave 2-10 times higher activity than the customary Et_2AlCl cocatalyst.

The percent heptane insolubles (% HI) decreased substantially using the new cocatalysts. Thus, these high activity catalysts are attractive for making low crystallinity homopolymers of propylene and higher alpha olefins. They are particularly attractive for making thermoelastic polymers and amorphous copolymers and terpolymers for elastomers.

EXAMPLE 12

A titanium catalyst containing $MgCl_2$ was prepared by dry ball milling 4 days a mixture of anhydrous $MgCl_2$ (1 mole), $TiCl_4$ (1 mole) and δ-$TiCl_3$ (0.1 mole). Propylene was polymerized using the conditions in Example 11, Run B and the quantities shown in Table VII. Activity with the cocatalysts of this invention (Run L) was intermediate between those of the $AlEt_3$ and $AlEt_2Cl$ controls (Runs J and K), but the stereospecificity as shown by % HI was much higher than the controls. The large increase in % HI obtained with this $MgCl_2$-containing catalyst is in contrast to the results in Example 1 using $TiCl_3$ catalysts in which activity increased sharply but % HI decreased.

TABLE VII

Run	Catalyst	Alkyl Metals	Rate g/g Cat/hr	% HI
J(Control)	1	10 $AlEt_3$	79	54.4
K(Control)	1	10 $AlEt_2Cl$	18	35.8

L	0.2	1 $AlEtCl_2$ + 1 $(s\text{-}Bu)_2Mg$	42	81.0

EXAMPLE 13

A titanium catalyst was prepared by dry ball milling 4 days a mixture of 5 $MgCl_2$, 1 $TiCl_4$ and 1 ethyl benzoate, heating a slurry of the solids in neat $TiCl_4$ 2 hours at 80°C., washing with n-heptane and vacuum drying. The catalyst contained 3.78% Ti.

Propylene was polymerized following the procedure of Example 11, Run B except that supported catalyst was used. As shown in Table VIII, all the control runs (M through S) gave substantially lower activity and/or % HI than the $AlEtCl_2$ + s-Bu_2Mg combination (Run T) or $AlCl_3$ + s-Bu_2Mg (Run U).

If the new cocatalysts simply reacted as the separate alkyl metal compounds, the results should have been like Runs M + Q. If the new cocatalysts simply reacted according to the equation: $AlRCl_2 + R_2Mg$ $AlR_2Cl + RMgCl$, then the results should have been like Runs N + P. However, the results in Run T and U are dramatically better, showing the completely unexpected formation of R_2AlR' as previously defined.

A much smaller synergistic effect was obtained by combining $AlEt_2Cl$ + s-Bu_2Mg (Run S), but the results were poorer than those obtained with $AlEt_3$. Combining s-Bu_2Mg with $AlEt_3$ (Run R) destroyed the activity shown by $AlEt_3$ alone (Run O). Thus, the outstanding results were obtained only when R_2Mg was combined with $RAlCl_2$ or $AlCl_3$.

TABLE VIII

Run	Catalyst	Mmoles Al Cpd	Mmoles Mg Cpd	Time Hrs.	Rate g/g Cat/hr	% HI
M(Control)	0.2	1 $AlEtCl_2$	--	0.5	0	--
N(Control)	0.2	1 $AlEt_2Cl$	--	1	47	61.1
O(Control)	0.2	1 $AlEt_3$	--	1	326	82.6
P(Control)	0.2	--	0.83 s-Bu MgCl	0.25	0	--
Q(Control)	0.2	--	0.83 $(s\text{-}Bu)_2Mg$	0.25	0	--
R(Control)	0.2	1 $AlEt_3$	0.83 $(s\text{-}Bu)_2Mg$	0.25	--	--
S(Control)	0.2	1 $AlEt_2Cl$	0.83 $(s\text{-}Bu)_2Mg$	1	165	80.5
T	0.2	1 $AlEtCl_2$	0.83 $(s\text{-}Bu)_2Mg$	1	367	91.9
U	0.2	1 $AlCl_3$	0.83 $(s\text{-}Bu)_2Mg$	1	220	88.9

EXAMPLE 14

The procedure of Example 13 was followed using 0.2g of the supported $TiCl_4$ catalyst together with $(s\text{-}Bu)_2Mg$ and various aluminum compounds.

TABLE IX

Run	Mmoles Al Cpd	Mmoles $(s\text{-}Bu)_2Mg$	Time Hrs.	Rate g/g Cat/hr	% HI
V	0.4 $AlEtCl_2$	0.33	1	60	94.5
W	1 $AlEtCl_2$	0.41	1	64	76.6
X	0.5 $AlEtCl_2$	0.83	1	260	87.2
Y	0.5 $AlCl_3$	0.83	2	136	90.7
Z	1 $AlEtCl_2$ + 1 $AlEt_2Cl$	0.83	1	404	86.9
AA	1 $AlEtBr_2$	0.83	1	220	88.9
BB	1 $AlC_8H_{17}Cl_2$	0.83	1	425	88.0
CC	0.63 $EtClAlN(iPr)_2$	0.53	1	6	--
DD	1 $Br_2AlN(iPr)_2$	0.83	1	16	--

Comparison of Runs V, W and X shows that the highest % HI is obtained at approximately equimolar amounts of $RAlCl_2$ and R_2Mg (Run V), that a large excess of $RAlCl_2$ is undesirable (Run W) and that a small excess of R_2Mg increases activity (Run X). Activity also increased upon addition of $AlEt_2Cl$ to the $AlEtCl_2$-$(s\text{-}Bu)_2Mg$ system (Run Z). The remainder of the experiments show that the dibromide may be used in place of dichloride (Run AA), that long chain alkyl aluminum compounds are very effective (Run BB), but that dialkyl amide groups on the aluminum compound destroy catalyst activity (Runs CC and DD).

EXAMPLE 15

The procedure of Example 13, Run T was followed except that Lewis bases were also added to the $AlEtCl_2$-$(s\text{-}Bu)_2Mg$ cocatalysts.

Addition of Lewis bases causes a decrease in catalyst activity until it becomes zero at a mole ratio of one strong base per mole of $RAlCl_2$ + R_2Mg (Table X).

TABLE X

Run	Mmoles Base/(sec-Bu)$_2$Mg	Time, Hrs.	Rate g/g Cat/hr	% HI
EE	0.24 ∅COOEt[a]	0.5	174	94.3
FF	0.5 Et_3N[b]	1	62	85.5
GG	2 Diisopentyl ether	1	127	78.8
HH	2 Tetrahydrofuran[c]	1	0	--

(a) Added to the (s-Bu)$_2$Mg.

(b) Premixed total catalyst in 100 ml n-heptane at 65°C., 5 min. before adding Et_3N.

(c) Added to premixed $AlEtCl_2$-(s-Bu)$_2$Mg.

As shown in Run EE, small quantities of Lewis base are effective in improving isotacticity (94.3% HI vs. 91.9 in Run T) while maintaining high activity (nearly 9 times the conventional $AlEt_2Cl/TiCl_3 \cdot 0.33\ AlCl_3$ catalyst, Example 11, Run H).

EXAMPLE 16

The procedure of Example 13, Run T was followed except that xylene diluent was used for polymerization instead of n-heptane. Activity was 676 g/g Cat/hr and the polymer gave 90.9% heptane insolubles. The polymer was precipitated with 1 liter isopropyl alcohol, filtered, dried and analyzed for metals. Found 13 ppm Ti and 83 ppm Mg. Thus at high monomer concentration and longer polymerization times the high efficiency would yield very low catalyst residues without deashing.

EXAMPLE 17

The procedure of Example 13, Run T was followed except that polymerization was carried out at 50°C. and 80°C. Both polymerization rate and % HI decreased with increasing temperature, with the largest decrease taking place above 65°C. (Table XI).

TABLE XI

Run	Polymer Temp, °C.	Time Hours	Rate	% HI
II	50	1	474	90.4
T	65	1	367	91.9
JJ	80	0.5	148	74.6

EXAMPLE 18

Propylene was polymerized at 690 kPa pressure in a stirred autoclave at 50°C, 1 hour. A second preparation of $MgCl_2$-containing $TiCl_4$ catalyst (2.68% Ti), made as in Example 13 except that $TiCl_4$-ethylbenzoate complex was preformed, was used in combination with $AlRCl_2$-R_2Mg. High stereospecificity was obtained at high rates and catalyst efficiencies (Table XII).

TABLE XII

Run	g Cat.	Mmoles $AlEtCl_2$	Mmoles $(s\text{-}Bu_2)Mg$	Rate	% HI
KK	0.10	0.5	0.5	1672	88.8
LL	0.10	0.25	0.25	696	95.0

EXAMPLE 19

The procedure of Example 13, Run T was followed except that the catalyst of Example 18 was used and 1 mmole di-n-hexyl magnesium was used instead of 0.83 mmole $(s\text{-}Bu)_2Mg$. The $(n\text{-hexyl})_2Mg$ in Soltrol No 10 was obtained from Ethyl Corporation (Lot No. BR-516). Polymerization rate was 551 g/g Cat/hr but the polymer gave 76.9% HI which is unacceptable. Thus n-alkyl magnesium compounds do not yield the high stereospecificity of the secondary and tertiary alkyl compounds of this invention.

EXAMPLE 20

The procedure of Example 15 Run EE was followed except that a new pure sample of $(sec\text{-}Bu)_2Mg$ was used with 0.33 mole diethyl ether instead of ethyl benzoate and the reaction time was 1 hr. Rate was 268 g/g Cat/hr and % HI = 92.2.

EXAMPLE 21

A catalyst was prepared by dry ball milling 4 days a mixture of 10 $MgCl_2$, 2 $TiCl_4$, 2 ethylbenzoate and 1 Mg powder, heating the solids in neat $TiCl_4$ 2 hours at 80°C., washing with n-heptane and vacuum drying (Ti = 2.16%).

Propylene was polymerized 1 hour at 65°C. and atmospheric pressure using 0.20 g of this catalyst under the conditions of Example 13, Run T except only 0.4 mmole $(s\text{-}Bu)_2Mg$ and 0.4 mmole $AlEtCl_2$ was used. Rate was 240 g/g Cat/hr and % HI = 93.9.

EXAMPLE 22

A catalyst was prepared by dry ball milling 1 day a mixture of 5 $MgCl_2$ and 1 ethylbenzoate, adding 1 $TiCl_4$ and milling an additional 3 days, then treating the solids with neat $TiCl_4$ 2 hours at 80°C., washing with n-heptane and vacuum drying (3.44 % Ti).

Propylene was polymerized following the procedure of Example 13, Run T, except that 1 mmole $(s\text{-}Bu)_2Mg$ was used instead of 0.83 mmole. Rate was 298 g/g Cat/hr and % HI = 89.

EXAMPLE 23

Following the procedure in Example 18, two catalysts were made at different Mg/Ti ratios. Catalyst A was made with 1 $MgCl_2$ + 1 $TiCl_4$-ethylbenzoate and B (2.10% Ti) was made with 10 $MgCl_2$ + 1 $TiCl_4$-ethylbenzoate complex. Propylene was polymerized following the procedure of Example 13, Run T (Table XIII).

TABLE XIII

Run	g Cat	Mmoles $AlEtCl_2$	Mmoles $(s\text{-}Bu)_2Mg$	Rate	% HI
MM	0.107A	2	1.66	60	72.0
NN	0.316B	0.25	0.25	512	60.4
OO[(a)]	0.316B	0.25	0.25	124	84.2

(a) Added 0.25 mmole triethylamine to the alkyl metal cocatalysts.

These results show that the 1:1 and 10:1 $MgCl_2$:$TiCl_4$ catalyst preparations were not as effective as the 5:1 preparations in preceding examples.

EXAMPLE 24

Polymerizations were carried out in a 1 liter baffled resin flask fitted with a reflux condenser and stirrer. In a standard procedure for propylene polymerizations, 475 ml n-heptane (<1 ppm water) containing the alkyl metal cocatalysts was charged to the reactor under N_2, heated to reaction temperature (65°C.) while saturating with propylene at 765 mm pressure. The powdered transition metal catalyst was charged to a catalyst tube such that it could be rinsed into the reactor with 25 ml n-heptane from a syringe. The propylene feed rate was adjusted to maintain an exit gas rate of 200-500 cc/min. After one hour at temperature and pressure, the reactor slurry was poured into 1 liter isopropyl alcohol, stirred 2-4 hours, filtered, washed with alcohol and vacuum dried.

A titanium catalyst supported on $MgCl_2$ was prepared by combining 5 $MgCl_2$, 1 $TiCl_4$ and 1 ethylbenzoate, dry ball milling 4 days, heating a slurry of the solids in neat $TiCl_4$ 2 hours at 80°C., washing with n-heptane and vacuum drying. The catalyst contained 3.78% Ti. Portions of this catalyst preparation were used in the experiments shown in Table XIV. Various control runs are shown for comparison with the cocatalysts of this invention (Runs A-F).

The sec-butyl magnesium was obtained from Orgmet and contained 72% non volatile material in excess of the s-Bu_2Mg determined by titration. IR, NMR and GC analyses showed the presence of butoxide groups and 0.07 mole diethyl ether per s-Bu_2Mg. The various s-BuMgX compounds were prepared directly by reacting an equimolar amount of ROH, RSH, RCOOH, etc. with the s-Bu_2Mg.

TABLE XIV

(0.2 g Catalyst, 500 ml n-C_7, 65°C., 1 hr.)

Run	Mmoles Al Cpd	Mmoles Mg Cpd	Mmoles Base	Rate g/g Cat/hr	% HI
Control	1 $AlEt_2Cl$	--	--	47	67.1
Control	1 $AlEt_3$	--	--	326	82.6
Control	1 $AlEt_2Cl$	0.83 $(s\text{-}Bu)_2Mg$	--	165	80.5
Control	1 $AlEt_3$	0.83 $(s\text{-}Bu)_2Mg$	--	6	--
Control	--	0.83 $(s\text{-}Bu)_2Mg$	--	0	--
Control	--	0.83 s-BuMgCl	--	0	--
A	1 $AlEt_2Cl$	1 s-Bu Mg OOCØ	--	165	95.2
B	1 $AlEt_2Cl$	1 s-Bu Mg $OC_{15}H_{31}$	--	276	91.7
C	1 $AlEt_2Cl$	1 s-Bu Mg OC_2H_5	--	261	91.4
D	1 $AlEt_2Cl$	1 s-Bu Mg $SC_{12}H_{25}$	--	310	93.2
E	1 $AlEt_2Cl$	0.83 s-Bu MgCl	1 Et_3N	100	94.6
F	1 $Et_2AlOOCØ$ + 1 Et (s-Bu)AlCl	1 s-BuMgCl	--	351	90.5

Compared to the control runs, which gave either low activity or low percent heptane insolubles (% HI), the new cocatalyst combinations gave high activity and stereospecificity (>90% HI).

EXAMPLE 25

A second catalyst preparation 2.68% Ti was made following the procedure of Example 24 except that a preformed 1:1 complex of $TiCl_4 \cdot \phi COOEt$ was used. In Runs G and H, the s-BuMgCl·Et_2O was obtained by vacuum stripping an ether solution of the Grignard reagent. In Run I, the n + s $BuMgOOCC_6H_5$ was made by reacting pure (n + s $Bu)_2Mg$ with benzoic acid. Propylene polymerizations were carried out as in Example 24 (Table XV).

TABLE XV

Run	Mmoles Al Cpd	Mmoles Mg Cpd	Mmoles Base	Rate g/g Cat/hr.	% HI
G	1 $AlEtCl_2$	1 s-BuMgCl	1 Et_2O	0	--
H	1 $AlEt_2Cl$	1 s-BuMgCl	1 Et_2O	132	93.1
I	1 $AlEt_3$	1 n + s-Bu $MgCOCC_6H_5$	--	123	89.7

Run G shows that monoalkyl aluminum compounds are not effective in combination with the mono-organomagnesium compounds in this invention. In contrast, Example 13, Run T, shows that such monoalkyl aluminum compounds are preferred when diorganomagnesium compounds are used.

Runs H and I show that dialkyl and trialkyl aluminum compounds are required with monoalkyl magnesium compounds.

EXAMPLE 26

Propylene was polymerized at 690 kPa pressure in a 1 liter stirred autoclave at 50°C. for 1 hour using the supported $TiCl_4$ catalyst of Example 25 (Table XV). The Mg compound was made as in Example 24, Run A.

TABLE XVI

Run	g Cat.	Mmoles Mg Cpd	Mmoles $AlEt_2Cl$	Solvent	Rate	% HI
J	0.05	0.5 s-BuMgOOCØ	0.5	n-C_7	1292	89.9
K	0.10	0.4 s-BuMgOOCØ	0.4	n-C_7	317	96.9
L	0.10	0.4 s-BuMgOOCØ	0.4	xylene	517	96.5

Comparison of Runs J and K shows that the lower alkyl metal/catalyst ratio in K gave higher heptane insolubles. Run L in xylene diluent gave higher activity than K in heptane.

EXAMPLE 27

The procedure of Example 25 was followed except that organomagnesium compounds containing alkoxy and benzoate groups were used in combination with $AlEt_2Cl$ together with diethyl ether. The s-BuMgOsBu was prepared by reacting a dilute solution of sBu_2Mg containing 0.33 Et_2O with one mole s-BuOH and used without isolation (Run M). The mixture in Run N was prepared in a similar manner by reacting 1.55 mmole n + s Bu_2Mg with 1.10 s-butanol, adding 0.066 Et_2O, then adding this product to a solution of 1 benzoic acid in 275 ml n-heptane.

TABLE XVII

Run	Mmoles Mg Cpd	Mmoles $AlEt_2Cl$	Mmoles Et_2O	Rate	% HI
M	1 s-BuMgOs-Bu	1	1/3	107	94.6
N	0.45 n+s BuMgOOCØ 0.55 n+s BuMgOsBu 0.55 s-BuOMgOOCØ	1	0.066	101	95.9

Comparison with Example 25, Run H shows that superior results were obtained with smaller amounts of diethyl ether by using alkoxide and carboxylate salts instead of the chloride.

EXAMPLE 28

The procedure of Example 7, Run Z was followed except that 0.25 mmole $Mg(OOCC_6H_5)_2$ was used in place of acetophenone as the third component. The magnesium benzoate was prepared from a dilute heptane solution of benzoic acid and n + s Bu_2Mg. The t-Bu_2AlEt was added to the milky slurry of $Mg(OOCC_6H_5)_2$, charged to the reactor and heated to 65°C., 5 min., after which the supported titanium catalyst was added.

The propylene polymerization rate was 122 g/g Cat/hr and polymer HI = 97.7%.

EXAMPLE 29

The procedure of Example 6, Run P, was followed except that magnesium benzoate was used as a cocatalyst modifier. The magnesium salt was made in situ by reacting a hydrocarbon solution of (n + s-Bu)$_2$Mg with two moles of benzoic acid. The salt slurry was reacted with the alkyl metal cocatalyst in 500 ml n-heptane at 25° to 65°C. to obtain a soluble product before the catalyst was added.

TABLE XVIII

Run	Mmoles Al Cpd	Mmoles Mg(OOCØ)$_2$	Rate	% HI
A(Control)	1 $AlEt_3$	--	241	82.3
B	1 $AlEt_3$	0.25	210	93.0
C	1 $AlEt_3$	0.50	0	--
D(Control)	1 t-Bu_2AlEt	--	248	93.8
E	1 t-Bu_2AlEt	0.25	125	97.7

When used in small amounts relative to the aluminum trialkyl cocatalyst, the magnesium benzoate sharply increased stereospecificity as measured by the percent boiling heptane insolubles (Runs B and E vs. A and D). Activity decreased somewhat, but the results for both rate and % HI were superior to those of conventional $TiCl_3$ catalysts (Example 11, Runs A, C, F and H). At a ratio of 0.5 Mg(OOCØ)$_2$ to $AlEt_3$, the catalyst was inactive (Run C). The modifier was effective with both types of aluminum trialkyls, but it gave the highest stereospecificity with the novel trialkyl aluminum cocatalysts of this invention.

EXAMPLE 30

The procedure of Example 29, Run B, was followed using various metal carboxylates as cocatalyst modifiers.

TABLE XIX

Run	Mmoles Salt	Rate	% HI
F	0.25 Mg acetate	175	94.7
G	0.25 Mg neodecanoate	235	91.8
H	0.25 Na stearate	206	92.4
I	0.25 K neodecanoate	211	90.8

Comparison with control Run A, Example 29, shows that much higher % HI was obtained while still retaining high activity.

EXAMPLE 31

The procedure of Example 29 was followed except that various dialkyl aluminum carboxylates were used instead of the magnesium salt. The aluminum trialkyl and carboxylate were premixed 3-5 minutes at 25°C. in 30 ml n-heptanes.

TABLE XX

Run	Mmoles Al Cpd	Mmoles Carboxylate	Rate	% HI
J	1 $AlEt_3$	1 $Et_2AlOOC\emptyset$	130	97.4
K	1 $AlEt_3$	1 s-$Bu_2AlOOC\emptyset$	232	95.5
L	1 s-Bu_2AlEt	1 $Et_2AlOOC\emptyset$	246	94.4
M	1 s-Bu_2AlEt	1 s-$Bu_2AlOOC\emptyset$	276	91.4
N	1 $AlEt_3$	1 $Et_2AlOOCC_6H_3Me_2$-2,6	262	89.1
O	1 s-Bu_2AlEt	1 $Et_2AlOOCC_6H_3Me_2$-2,6	310	77.7
P	1 $AlEt_3$[(a)]	1 $Et_2AlOOC\emptyset$[(a)]	70	97.8
Q	2 $AlEt_3$[(b)]	1 $Et_2AlOOC\emptyset$[(b)]	239	93.1
R	--	1 s-$Bu_2AlOOC\emptyset$	0	--

(a) Premixed 5 minutes in 30 ml n-heptane at 40-50°C.
(b) Premixed in 30 ml n-heptane at 60°C, 30 minutes.

Comparison with control Run A, Example 29, shows that increased stereospecificity was obtained with all of the alkyl aluminum carboxylates except in Run O. Higher activities were also obtained in some cases, especially with the 2,6-dimethylbenzoates (Runs N and O). The ortho substituents are believed to hinder the carbonyl addition reaction which leads to lower activity by consumption of the aluminum trialkyl. Support for this type of side reaction can be seen in the low activity in Run P, premixed in concentrated solution, compared to Run J which was premixed in 500 ml n-heptane. When sufficient excess AlR_3 is used in a concentrated premix with the aluminum benzoate, one regains activity, but the modifier is presumed to be the aluminum alkoxide products from the carbonyl addition reaction. Run R shows that the carboxylate compound alone is not a cocatalyst, so that the improved results obtained when mixed with AlR_3 must be due to the reaction of the AlR_3 with the carboxylate modifier.

EXAMPLE 32

The procedure of Example 29 was followed except that tertiary butyl aluminum compounds were used and the ratio of aluminum trialkyl to aluminum benzoate was varied.

TABLE XXI

Run	Mmoles Al Cpd	Mmoles Carboxylate[a]	Rate	% HI
S	1 t-Bu_2AlEt	0.25 t-Bu_2AlOOCØ	221	93.4
T	1 t-Bu_2AlEt	0.50 t-Bu_2AlOOCØ	227	94.9
U	1 t-Bu_2AlEt	1.0 t-Bu_2AlOOCØ	184	94.6

(a) May contain some t-Bu EtAlOOCØ as it was prepared by reacting t-Bu_2AlEt with ØCOOH.

Comparison with Example 29 shows that the dialkyl aluminum benzoates were not as efficient as magnesium benzoate, and higher ratios were needed to achieve higher stereospecificity.

EXAMPLE 33

The procedure of Example 6, Run P, was followed except that dialkyl aluminum alkoxides were used as co-catalyst modifiers.

TABLE XXII

Run	Mmoles AlR_3	Mmoles Al Alkoxide	Rate	% HI
V	0.8 t-Bu_2AlEt	0.2 t-$Bu_2AlOCMeEt$Ø	196	94.2
W	0.8 t-Bu_2AlEt	0.2 t-$Bu_2AlOCEt$$Ø_2$	191	94.6
X*	1 $AlEt_3$	--	506	81.6
Y*	1 $AlEt_3$	10 $Et_2AlOC_{15}H_{31}$	113	95.5

* Another catalyst preparation was used (contained 3.16% Ti).

Comparison of Runs V and W with control run D, Example 29, shows that the alkoxide additives increased stereospecificity as measured by heptane insolubles. This was also true for Run Y versus its control (Run X). In this case, a large excess of alkoxide was used relative to the AlR_3. These results are opposite to those using unsupported $TiCl_3$ catalysts in which it is known that dialkyl aluminum alkoxide cocatalysts produce low heptane insoluble products.

Since many modifications and variations of this invention may be made without departing from the spirit or scope of the invention thereof, it is not intended to limit the spirit or scope thereof to the specific examples thereof.

CLAIMS

1. A catalyst composition suitable for use in polymerizations which comprises a mixture of:

(a) a titanium metal compound on a support, said titanium metal being $TiCl_3$, $TiCl_4$, $TiBr_3$, $TiBr_4$ or a mixture thereof;

(b) at least one alkyl metal compound having the formula. $R_nMR'_{3-n}$; wherein R' is a C_1 to C_{20} primary alkyl, alkenyl or aralkyl group or hydrogen, M is Al, Ga or In, R is a C_3-C_{20} secondary or tertiary alkyl, neopentyl alkyl, cycloalkyl or a secondary or tertiary alkenyl or aralkyl group , n is equal to 0-2; wherein said composition includes at least one Lewis base with the proviso that the Lewis base does not cause excessive cleavage of metal- -carbon bonds or loss of active sites, the molar ratio of said alkyl metal compound to said transition metal compound being about 0.5:1 to 200:1; and

(c) a salt of a Group IA to Group IIIB metal, said salt being an alkoxide, carboxylate or aryloxide, the concentration of said metal salt being about 0.1 to 20 moles of said $R_nMR'_{3-n}$ compound.

2. A catalyst composition suitable for use in polymerizations which comprises a mixture of:

(a) a titanium metal compound on a support, said titanium metal compound being $TiCl_3$, $TiCl_4$, $TiBr_3$, $TiBr_4$ or a mixtures thereof;

(b) at least one alkyl metal compound having the formula $R_3''M$ wherein M is Al, Ga or In and R" is C_1-C_{20} primary alkyl, secondary alkyl, tertiary alkyl, cycloalkyl, alkenyl or an aralkyl group, wherein said composition includes at least one Lewis base with the proviso that the Lewis base does not cause excessive cleavage of metal-carbon bonds or loss of active sites, the molar ratio of said $R_3''M$ to said transition metal compound being about 0.5:1 to about 200:1; and

(c) a salt of a Group IA to Group IIIB metal, said salt being an alkoxide, carboxylate or aryloxide, the concentration of said metal salt being about 0.1 to about 20 moles per mole of said $R_3''M$ compound.

3. A Composition according to either of claims 1 and 2 wherein said support comprises $MgCl_2$.

4. A composition according to any one of the preceding claims wherein said Lewis base is a carboxylic acid ester.

5. A composition according to any one of claims 1 to 3 wherein said Lewis base is a tertiary amine, ester, phosphine, phosphine oxide or phosphate or a mixture thereof.

6. A composition according to any one of claims 1 to 3 wherein said Lewis base is an aryl phosphate, alkyl phosphite, hexaalkyl phosphinic triamide, dimethyl sulfoxide or a mixture thereof.

7. A composition according to any one of claims 1 to 3 wherein said Lewis base is dimethyl formamide, a secondary amine, ether, epoxide, ketone or a mixture thereof.

8. A composition according to any one of claims 1 to 3 wherein said Lewis base is a saturated or unsaturated heterocycle, a cyclic ether or a mixture thereof.

9. A composition according to any one of the preceding claims wherein the titanium metal compound is a mixture of $TiCl_4$ and $TiCl_3$.

10. A composition according to any one of claims 1 to 8, wherein said titanium metal compound is $TiCl_4$ containing $MgCl_2$.

11. A composition according to any one of the preceding claims wherein the alkyl metal compound is $RAlR'_2$ and is formed from the reaction.

product of R'_2AlX and $RMgX'$, wherein X is a chloride, bromide or a monovalent anion which cannot initiate polymerization of olefinic monomers and X' is an anion which cannot initiate polymerization of olefinic monomers.

12. A composition according to any one of claims 1 to 10, wherein the alkyl metal compound is R_2AlR' and is formed from the reaction product of R_2Mg and $R'AlX_2$ wherein X is chloride, bromide or a monovalent anion which cannot initiate polymerization of olefinic monomers.

13. A composition according to any one of the preceding claims, wherein the Group IA-IIIB metal is magnesium or aluminium.

14. A process for the polymerization of a C_2 to C_{20} olefinic monomer or a mixtures thereof to a homo-, co- or terpolymer which comprises contacting said monomer with a catalyst composition according to any one of the preceding claims.

European Patent Office

EUROPEAN SEARCH REPORT

0005326

Application number

EP 79 30 0613

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
	DE - A - 2 724 971 (MITSUI) * Claims 1-9,11,12; page 14, line 2 - page 17, line 1; page 20, lines 9-21 * --	1,2,4-8,13,14
A	FR - A - 2 342 297 (TEXAS ALKYLS) * Claims 1,10,11; page 1, lines 1-6 * --	1
A	FR - A - 1 425 247 (HOECHST) * Abstract 1-3 * --	1
A	FR - A - 1 412 113 (HOECHST) * Abstract 1; page 2, left-hand column, paragraph 2 * --	1
A	FR - A - 2 322 158 (MONTEDISON) * Claims 1,8 * ----	1

CLASSIFICATION OF THE APPLICATION (Int. Cl.²)

C 08 F 10/00
4/60
4/02

TECHNICAL FIELDS SEARCHED (Int.Cl.²)

C 08 F 10/00-
10/14
110/00-
110/14
210/00-
210/18
4/02

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	04-07-1979	WEBER

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